INNOVATIVE TECHNOLOGY
Summary Report

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Pipe Cutting and Isolation System

Tanks Focus Area

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Innovative Technology
Summary Report

Pipe Cutting and Isolation System

OST Reference #2093

Tanks Focus Area

Demonstrated at
Oak Ridge National Laboratory
Oak Ridge, Tennessee

Innovative Technology Summary Report

Purpose of this document

Innovative Technology Summary Reports are designed to provide potential users with the information they need to quickly determine if a technology would apply to a particular environmental management problem. They are also designed for readers who may recommend that a technology be considered by prospective users.

Each report describes a technology, system, or process that has been developed and tested with funding from DOE's Office of Science and Technology (OST). A report presents the full range of problems that a technology, system, or process will address and its advantages to the DOE cleanup in terms of system performance, cost, and cleanup effectiveness. Most reports include comparisons to baseline technologies as well as other competing technologies. Information about commercial availability and technology readiness for implementation is also included. Innovative Technology Summary Reports are intended to provide summary information. References for more detailed information are provided in an appendix.

Efforts have been made to provide key data describing the performance, cost, and regulatory acceptance of the technology. If this information was not available at the time of publication, the omission is noted.

All published Innovative Technology Summary Reports are available on the OST Web site at http://OST.em.doe.gov under "Publications."

TABLE OF CONTENTS

SECTION 1

SUMMARY

Technology Summary

The Gunite and Associated Tanks (GAAT) at the U.S. Department of Energy (DOE) Oak Ridge Reservation (ORR) contain several openings for pipes that were once used to deliver radioactive waste to the tanks. During rainstorms and for several days afterwards, ground water leaks through these pipes into the tanks. This water then becomes part of the tank waste that must be retrieved and processed as radioactive waste. These tanks need to be isolated to prevent ground water from leaking into the tanks after retrieval activities have been completed.

In the past, tanks were isolated by hand excavation and plugging pipes from the exterior of the tanks. This method is complicated by the lack of reliable methods to locate the pipelines entering tanks. Other disadvantages include the cost of hand excavation and the potential for worker contamination. Hand excavation also generates significant quantities of waste that must be treated and disposed of during tank closure operations.

The Tanks Focus Area developed an improved method and tools for plugging pipelines from inside the tank. The tools were deployed in FY98 and FY99 at Oak Ridge. While cost savings were achieved, the primary driver for this deployment was reduced worker exposure.

How It Works
The Pipe Cutting and Isolation System consists of three new tools developed for use inside a tank to seal pipes. These tools are a Pipe Cutting Tool, a Pipe Cleaning Tool, and a Pipe Plug Assembly. Figure 1 illustrates the first pipe plugging deployment in GAAT W-6 at the Oak Ridge National Laboratory (ORNL).

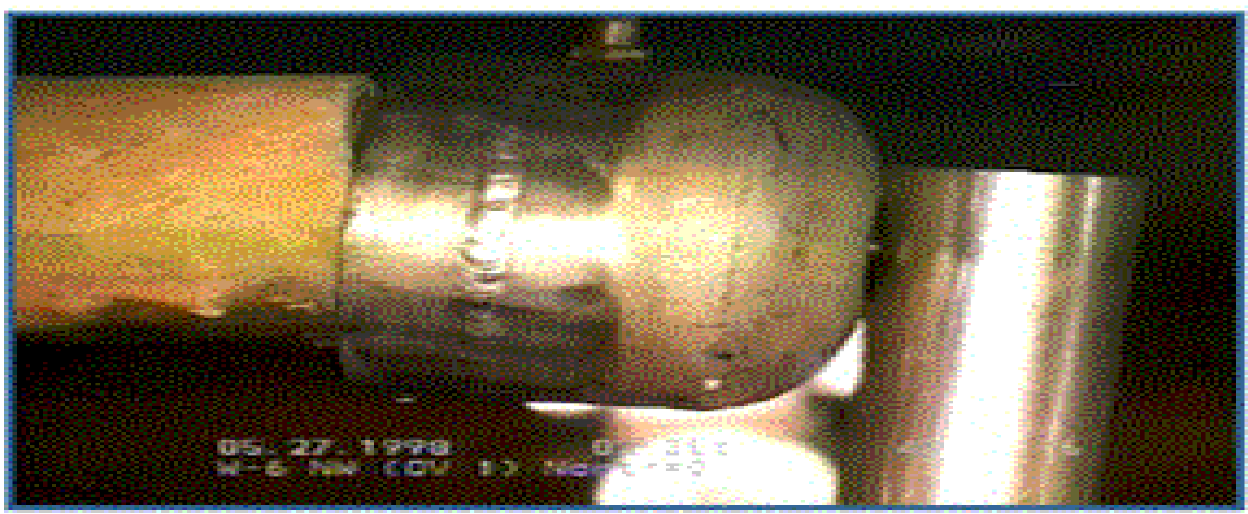

Figure 1. First pipe plugging deployment in GAAT W-6 at Oak Ridge National Laboratory.

The new approach to tank isolation involves the following tasks:

- Cut pipes as needed in preparation for pipe plugging. Vertical pipes require cutting to access the pipes' ends. Horizontal pipes may require cutting as well.
- Clean pipes as needed to remove scales and deposits from the outside and inside of pipe ends.
- Plug pipes as needed to provide a seal against ground-water intrusion.

Advantages Over Baseline

The baseline technology is external pipe plugging, which requires excavation of soil around the tanks, cutting, and plugging of pipes. This method has resulted in workers' being contaminated. The Pipe Cutting and Isolation System presents several advantages over the baseline method:

- The system significantly reduces worker exposure to radiation.
- The system can be installed quickly and efficiently.
- The system generates significant cost savings over the baseline method.

Potential Markets

This technology will be deployed in other tanks at ORNL. The system may be applicable in pipe cutting and isolation operations in other hazardous and nonhazardous waste tanks across the DOE complex, including the Hanford Site and Idaho National Engineering and Environmental Laboratory (INEEL). Tanks in the private sector may be isolated by this technology as well.

Demonstration Summary

The Pipe Cutting and Isolation System was successfully deployed at the ORNL South Tank Farm in FY98 and FY99.

- The Pipe Plug Assembly was successfully deployed on May 27, 1998 in GAAT W-6. The pipe plug stopped inleakage of ground water and significantly improved the vacuum control on the tank.

- The Pipe Cutting Tool was successfully deployed on October 7, 1998 in GAAT W-7 and in four subsequent cutting operations.

- The Pipe Cleaning Tool was deployed in GAAT W-7 on January 21, 1999. Electrical operation of the tool and the feasibility of its deployment inside a tank were verified.

The Pipe Cutting and Isolation System was proven effective in isolating underground storage tanks. System operations were performed in much less time than required for alternative methods. Significant cost savings were achieved over the baseline technology.

Participants

The following parties contributed to successful deployment of the Pipe Cutting and Isolation System:

- The Tanks Focus Area
- DOE Office of Science and Technology (OST)
- DOE Office of Environmental Restoration (ER)
- ORNL
- Sandia National Laboratory
- Lockheed Martin Energy Research Corporation
- Pacific Northwest National Laboratory (PNNL)

Commercial Availability

Tools used for pipe cutting and cleaning are commercially available from hardware stores; however, adaptations are required for robotic positioning. The pipe plugging technology is being patented.

Future Plans

The following tank isolation activities are planned at ORR:

- Continue using the system for removing obstructions and for in-pipe plugging operations.
- Investigate design improvements to minimize potential problems.
- Deploy the system on a broader range of pipe configurations.

Contacts

Technical

Benjamin E. Lewis, Principal Investigator, Lockheed Martin Energy Research Corporation, Phone: (423) 574-4091, E-mail: lew@ornl.gov

Richard L. Glassell, Modified Light-Duty Utility Arm System Lead, The Providence Group, Phone: (423) 927-5519

Management

Kurt Gerdes, Tanks Focus Area Office of Science and Technology Program Manager, DOE Headquarters, Phone: (301) 903-7289 E-mail: kurt.gerdes@em.doe.gov

Ted Pietrok, Tanks Focus Area Program Manager, DOE Richland Operations Office, Phone: (509) 372-4546, E-mail: theodore_p_pietrok@rl.gov

Jacquie Noble-Dial, Oak Ridge Operations Tanks Focus Area Manager, DOE, Phone: (423) 241-6184, E-mail: nobledialjr@ornl.gov

Other

All published Innovative Technology Summary Reports are available on the OST Web site at http://ost.em.doe.gov under “Publications.” The Technology Management System, also available through the OST Web site, provides information about OST programs, technologies, and problems. The OST reference number for the Pipe Cutting and Isolation System is 2093.

SECTION 2

TECHNOLOGY DESCRIPTION

Overall Process Definition

Goals for deploying the Pipe Cutting and Isolation System include the following:

- provide an effective means of isolating underground storage tanks,
- perform isolation activities inside a tank rather than externally, and
- eliminate or significantly reduce the risk of worker contamination.

This section describes the technology and outlines the steps in the GAAT isolation process. Complete details and step-by-step instructions for preparing, deploying, operating, and retracting each of the three system tools are located in procedure numbers GAAT-RP/P-134, Rev. 0; GAAT-RP/P-148, Rev. 1; and GAAT-RP/P-149, Rev. 1.

In preparation for tank closure, tank isolation activities begin after completing waste retrieval. Pipes requiring isolation are identified. These pipes are then cut, cleaned, and plugged as needed using the following tools: (1) Pipe Cutting Tool, (2) Pipe Cleaning Tool, and (3) Pipe Plug Assembly. The Pipe Cutting Tool consists of a standard industrial band saw weighing approximately 40 lb. The Pipe Cleaning Tool consists of a wire brush operated by a drill motor. The Pipe Plug Assembly consists of seven components as identified later in Table 1. The Modified Light-Duty Utility Arm (MLDUA) deploys the tools. Remote viewing and lighting systems are used inside the tank to monitor operations.

The MLDUA is telerobotically operated and has seven degrees of freedom and a telescoping vertical mast. For tank isolation activities, it is equipped with a removable, general-purpose Gripper End Effector (GEE). In the 25-ft-diameter tanks in the North Tank Farm, the MLDUA can reach the walls from a central riser. In the 50-ft-diameter gunite tanks, the reach coverage area is restricted because of the location of the peripheral risers. When the MLDUA cannot reach pipes requiring isolation, a second robotic device is also used. In these cases, the MLDUA deploys the tools in the tank and hands the tools to the Houdini Remotely Operated Vehicle (ROV). The ROV is a tracked vehicle that folds to reduce the effective diameter for deployment and retrieval through 30-inch-diameter risers. It is equipped with a Schilling Titan III six–degree of freedom manipulator and a plow blade.

Pipe Cutting Operation

Figure 2 shows the Pipe Cutting Tool. Pipes to be isolated are identified and analyzed to determine whether they need to be cut. If cutting is not required, the pipe cutting operation is skipped. Otherwise, the appropriate length for the pipes to be cut is determined. The Pipe Cutting Tool is then attached to the MLDUA via the GEE. The MLDUA positions the Pipe Cutting Tool near or against the pipe to be cut. The Pipe Cutting Tool is powered. The MLDUA moves the tool blade through the pipe. After cutting and cooldown, the MLDUA positions the tool near the next pipe to be cut, if required. The MLDUA is retracted from the tank when pipe cutting is complete.

Pipe Cleaning Operation

Figure 3 shows the Pipe Cleaning Tool. It is attached to the MLDUA via the GEE grippers. The MLDUA positions the Pipe Cleaning Tool brush near or against the pipe to be cleaned. The tool is powered to start pipe cleaning. After cleaning and cooldown, the MLDUA positions the tool near the next pipe to be cleaned, if required. The MLDUA is retracted from the tank when pipe cleaning is complete.

Pipe Plugging Operation

Figure 4 shows the Pipe Plug Assembly. The components of the Pipe Plug Assembly are listed in Table 1 along with their functions, characteristics, and placement instructions. The pipe plug is assembled at a specified clean site away from the tank area. The pipe plug is carried to the tank riser interface and confinement area and passed inside using the pass-through port.

Figure 2. Pipe Cutting Tool deployed in GAAT W-7.

Figure 3. Pipe Cleaning Tool.

Figure 4. Pipe Plug Assembly.

Table 1. Components of the Pipe Plug Assembly

Component	Function	Characteristics	Placement
Metal cup	The cup holds the sealant.	The inner diameter of the stainless steel cup is larger than the outer diameter of the pipe to be plugged.	This cup is placed over the pipe.
Rod	A threaded stainless steel rod holds the alignment guide, gasket, and centering guide in position.	The rod is longer than the length of the cup.	This rod is attached to the center of the cup using nuts on either side of a hole in the bottom of the cup. The outside nut can also be used to attach the handle to the cup.
Alignment guide	The alignment guide helps the robotic arm guide the cup onto the pipe end.	The guide is cone shaped and can be constructed of either metal or plastic.	This guide is attached to the end of the center rod on the open end of cup.
Centering guide	The centering guide allows the cup to slide onto the pipe. It prevents the cup from sliding off the pipe, which is important for vertical pipes. For horizontal pipes, the centering guide assists in holding the plug concentric with the pipe.	This guide is a thin, stainless steel plate made of spring steel. It is shaped like a star with six arms that bend away from the cup's opening and toward the bottom of the cup.	This guide is mounted on the center rod between the alignment guide and the bottom of the cup. Positioning nuts are threaded onto the center rod to hold the centering guide in place.
Gasket	The gasket prevents or minimize the amount of sealing material that may flow out of the cup while the cup is positioned near a pipe to be plugged and when the plug is mounted to a pipe.	The gasket is flexible and acts as a seal.	This gasket is mounted between the alignment guide and the centering cone.
Handles	A handle attached to the cup allows the MLDUA and ROV to hold the cup.	The MLDUA requires an X-handle, and the ROV requires a T-handle.	The location of the handle depends on the cup orientation required to plug the pipe.
Sealant	The sealant hardens to completely plug a pipe according to the following time allotments: • 4 h working time for epoxy, • 8–12 h to harden, and • 48 h at ambient temperature to fully cure.	The working consistency of epoxy is similar to peanut butter. It does not flow readily out of the cup, even when the cup is upside down.	Sealant is placed inside the cup. The cup is upside down during maneuvering of the MLDUA into the tank.

The MLDUA and GEE are positioned to hold the pipe plug. The pipe plug is placed into the GEE gripper, and the MLDUA is deployed into the tank. The MLDUA installs the pipe plug over the pipe end. Because of the limited life of the pipe plugging epoxy, this procedure must be completed within 4 h.

System Operation

Table 2 summarizes operational requirements for the Pipe Cutting and Isolation System. Detailed requirements are documented in Babcock, Glassell, and Lewis (1997).

Table 2. Operational requirements for the Pipe Cutting and Isolation System

Operational area	Requirement
Operational parameters and conditions	• System tools shall have a life expectancy of five years. • Operators must ensure the falling pipe section will not damage the MLDUA or any other equipment in the tank. • The power control pendant ammeter must be monitored for any motor current change that may indicate the blade is binding. During cutting operations, the motor current may rise to about 6 amps. • The pipe plugging operation shall be completed within 4 h of mixing the epoxy. • Pipe plug seals shall last at least 20 years. • Pipes to be plugged shall be suitable for plugging, i.e., not badly rusted. • Pipes to be plugged shall extend into the tanks at least 2 inches.
Materials	• Materials used to make the pipe plug shall be nonreactive and chemically compatible with chemicals expected to be in the pipeline and tank. • Epoxy components must be properly handled. Epoxy shall be mixed in a well-ventilated area (or outside) to avoid inhalation of unmixed components. • Operators shall wear rubber gloves and safety glasses while mixing and handling epoxy. • Neither mixed epoxy nor any of its components shall come in contact with skin. If this occurs, the skin shall be washed immediately with soap and water. • Epoxy components shall be stored in a cool, dry location. • Material safety data sheets shall be available to workers.
Technical skills/ training	• Workers' training and knowledge shall include the following areas: - use of the robotic systems used to deploy the tools, - quality assurance and control procedures, - health and safety plans and procedures, - health physics requirements, - regulatory requirements, and - monitoring and inspection of system operations.
Concerns/risks	• Interlocks and/or administrative controls must prevent unexpected operation of the system during tool changeout or during loss of power. • All system functions shall be controllable locally and remotely. • A guard shall cover the Pipe Cutting Tool blade at all times and shall be removed just before the tool is deployed into the tank.

SECTION 3

PERFORMANCE

Demonstration Plan

System tools were successfully deployed at the ORNL South Tank Farm during FY98 and FY99. The South Tank Farm consists of six 50-ft-diameter underground gunite tanks that were constructed in the 1940s. The six tanks—W-5, W-6, W-7, W-8, W-9, and W-10—are identical in construction except for the discharge piping inside the tanks. Each of the six tanks has a different piping configuration as follows:

- Number and size
  - There are approximately 50 pipes in all six tanks, with varying numbers in each tank.
  - Pipes are believed to be 1.5, 2, and 3 inches in diameter, although other sizes are suspected.

- Orientation
  - Horizontal pipes are near the ceiling. Pipe extensions in tanks vary from a few inches to several feet.
  - Vertical pipes terminate near the tank floors. Distances between the floors and pipes are unknown due to waste coverage. Some pipes appear to be grouped into bundles with unknown separation between pipes.

- Condition
  - Many pipes have a buildup of solid material near the outlet caused from discharging wastes. These pipes may require cleaning prior to plugging.

Major Objectives
DOE's major objectives for deploying this technology were to prevent ground water from leaking into underground storage tanks and to prevent workers from being contaminated by trying to plug the pipes externally. At Oak Ridge, tools were deployed using the MLDUA to provide a safer, more efficient, and more effective means for plugging pipes using a simple approach.

Table 3 identifies the major elements evaluated during deployment and the associated success criteria.

Table 3. Major elements evaluated during deployment of the Pipe Cutting and Isolation System

Element	Success criteria
Installation	• Tools easily attach to the MLDUA or ROV. • Tools fit through riser openings. • Tools are operable inside tanks.
Operation	• Tools operate using either the MLDUA or ROV. • The cutting tool is lightweight, easy to use, and produces a clean cut with minimal vibration. • The cleaning tool removes the buildup of material that has collected and formed a visible lip on the pipe end. • The pipe plug prevents ground water inleakage within 4 h of the time the epoxy is mixed.
Worker safety	• Worker exposure to radioactive waste is minimal.
Maintenance	• The majority of maintenance on the tools is performed in a controlled environment without risk for worker exposure.

Results

The Pipe Cutting and Isolation System was proven effective in isolating underground storage tanks. Commercial, off-the-shelf tools were successfully adapted for in-tank use. Significant cost savings were achieved over the baseline technology. Results of the testing and demonstration phases are summarized in the following sections.

Testing
In FY98, PNNL conducted tests at Hanford on the cutting and cleaning tools. The Light-Duty Utility Arm (LDUA) at the Cold Test Facility was used for tests. A 2-inch-diameter stainless steel pipe was cut in approximately 20–25 seconds using the band saw and the LDUA. The band saw produced a clean cut with almost no vibration. PNNL also supported the design and testing of the Pipe Plug Assembly.

A pipe plug test stand was constructed at ORNL (Figure 5). On March 27, 1998, a 3-inch pipe was plugged on the test stand, and on May 15, 1998, a 1½-inch pipe was plugged on the test stand. Both plugs successfully prevented leaking under 60 psig of water pressure through December 1998. Pressure tests will continue through FY99.

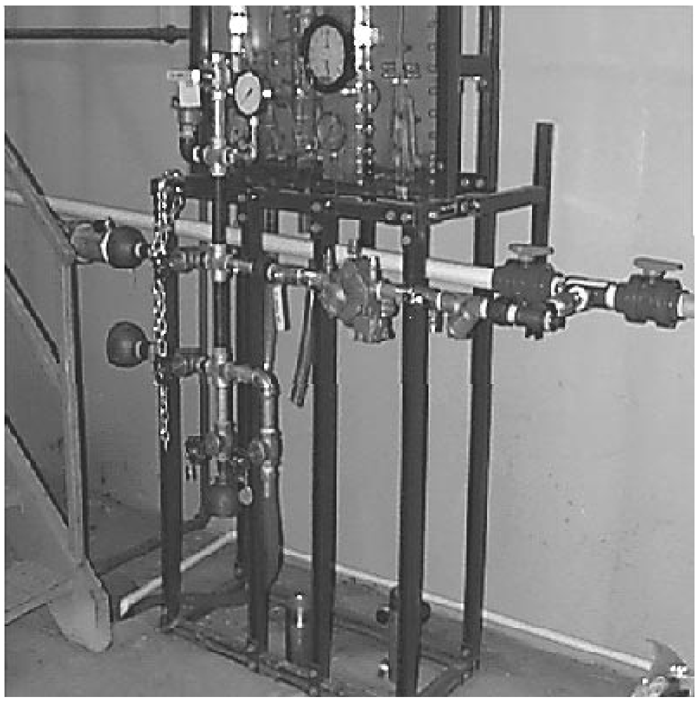

Figure 5. Pipe plug test stand.

Deployments
The Pipe Plug Assembly was successfully deployed in GAAT W-6 on May 27, 1998. This deployment involved plugging only. The pipe was not cut or cleaned prior to installation. Details are highlighted in Table 4.

Table 4. Performance results of the Pipe Plug Assembly

Deployment	Location	Pipe size and type	Performance
05/27/98	GAAT W-6, ORR	3-inch diameter horizontal	• The plug stopped ground water from leaking into the tank. • The operation lasted approximately 2 h from the time preparations began until installation was complete.

The Pipe Cutting Tool was successfully deployed in GAAT W-7 on October 7, 1998. Four additional cutting operations were completed after this first deployment. Table 5 describes the results of each cutting operation.

Table 5. Performance results of the Pipe Cutting Tool

Deployment	Location	Pipe size and type	Performance
1st operation 10/7/98	GAAT W-7 • South riser • ORR	2-inch diameter vertical	• The pipe was successfully cut, but the section of this pipe that remained in the ceiling unexpectedly fell to the floor. When the pipe fell, it trapped the cutting tool. • The MLDUA was used to break the saw blade on the cutting tool and free the system. • The Pipe Cutting Tool and MLDUA were not damaged. • The remaining pipe was cut the next day with no problems. • Pipe sections were left on the tank floor to be retrieved using the ROV.
2nd operation • 1st effort 11/19/98 • 2nd effort 11/30/98	GAAT W-7 • Near west riser • ORR	2-inch diameter vertical	1st effort • Excessive vibration of the cutting tool against the pipe broke the saw blade. 2nd effort • Using a more rigid MLDUA configuration than the previous one, the pipe was successfully cut. • The cutting operation required approximately 60 seconds. • The cutting tool did not vibrate excessively during operations. • Pipe cutting time inside the tank was significantly longer than cutting time measured during cold testing because of the added complications and viewing difficulties encountered during hot operations.
3rd operation 12/22/98	GAAT W-7 • North quadrant • ORR	2-inch diameter steel pipe	• The pipe was leaning inside the riser and was not attached to the tank. • When cut, the upper section fell to the tank floor and passed through the loop formed by the band saw blade. • A steel cable attached to the pipe end remained outside the band saw blade loop. • The steel cable was easily removed from the saw as the MLDUA was moved to the second 2-inch-diameter pipe.

Table 5. Performance results of the Pipe Cutting Tool (continued)

Deployment	Location	Pipe size and type	Performance
4th operation 12/22/98	GAAT W-7 • North quadrant • ORR	2-inch diameter steel pipe	• According to piping drawings for the South Tank Farm, this pipe was anchored to the roof of the tank by a 90-degree elbow and a length of additional horizontal buried piping. • When the pipe was cut, the upper section fell from the ceiling, leaving a 3- to 4-in-diameter hole in the top of the tank where the 2-inch-diameter pipe once entered. • The elbow and horizontal section of the pipe had apparently been cut off sometime in the past, but the piping drawings were not updated to reflect the change. • These events stress the uncertainty that exists on the accuracy of piping and layout drawings for DOE underground storage tanks.
5th operation 12/22/98	GAAT W-7 • North quadrant • ORR	½- to 1-inch-diameter stainless steel	• The pipe was successfully cut. • The upper section of pipe remained attached to the roof of the tank.

The Pipe Cleaning Tool was deployed in GAAT W-7 on January 21, 1999. See Table 6 for details.

Table 6. Performance results of the Pipe Cleaning Tool

Deployment	Location	Performance
1/21/99	GAAT W-7, ORR	• Electrical operation of the cleaning tool was verified. • Ability of the cleaning tool to be deployed inside a tank using the MLDUA was verified.

Time constraints and inclement weather prevented use of the tool in a pipe cleaning operation. An additional deployment of the cleaning tool in a needed pipe plugging operation is planned.

SECTION 4

TECHNOLOGY APPLICABILITY AND ALTERNATIVES

Competing Technologies

Alternative technologies were evaluated before selection of the Pipe Cutting and Isolation System tools. Technologies considered are shown in following three tables. Table 7 compares the chosen pipe cutting technology with available alternatives.

Table 7. Comparison of alternative pipe cutting technologies

Technology	Advantages	Disadvantages
Portable band saw (selected technology)	• Off-the-shelf band saw is used. • The band saw is lightweight and portable. • It has variable speeds. • It cuts cleanly and quickly. • Its 20-inch width enables its deployment through tank risers. • Blades are easy to change and are in a horizontal plane with the handles.	• The sharp blade presents a potential hazard for workers. • Workers must be trained to operate the robotic positioning equipment. • Vibration may cause the MLDUA to malfunction and break the blade.
Plasma torch	• The tool cuts pipes rapidly. • It is small and flexible. • Unit cost is low.	• A tether handling system is required. • The high-temperature flame inside a tank poses a risk.
High-pressure water jets	• This technology can be used inside a tank.	• High-pressure hoses and a handling system are required. • Implementation is expensive. • Liquid is added to the tank and must be treated as waste.
Lightweight shear (e.g., “Jaws-of-Life”)	• This tool performs well for cutting small pipes.	• This tool can cut only pipes that are 1-inch diameter or smaller. It is not sufficient for larger diameter pipes. • It tends to crush pipes.

Table 8 provides a comparison of pipe cleaning technologies.

Table 8. Comparison of alternative pipe cleaning technologies

Technology	Advantages	Disadvantages
Drill motor and rotating wire brush system (selected technology)	• Off-the-shelf drill motor is used. • Costs are low. • It is portable.	• Workers must be trained to operate the robotic positioning equipment.
Chemical cleaning	• Cleaning can be performed inside a tank.	• This method adds more liquid and waste inside a tank. • Adding chemicals poses greater risks.
Grinder	• This is a standard technology used by pipe fitters. • The tool can be used inside a tank.	• This technology is not applicable for this application.

Table 8. Comparison of alternative pipe cleaning technologies (continued)

Technology	Advantages	Disadvantages
High-pressure water jets	• This technology can be used inside a tank.	• High-pressure hoses and a handling system are required. • Implementation is expensive. • Jets require positioning extremely close to the pipes. • Jets require rotating. • Operation is difficult to control. • Liquid is added to the tank and must be treated as waste.

Table 9 provides a comparison of pipe plugging technologies.

Table 9. Comparison of alternative pipe plugging technologies

Technology	Advantages	Disadvantages
Sealant cup (selected technology)	• This technology is designed for implementation inside a tank, eliminating hazardous excavation.	• The minimum size that can be reasonably deployed is in the 1- to 1.5-inch range. It might be difficult to use if pipe is much smaller than this. • Workers will handle a chemical sealant with hazardous components. • Workers must be trained to operate the robotic positioning equipment.
Excavation, cutting, and capping (baseline)	• Tools are not limited by size restraints to fit into risers. • Viewing of operations is clearer. • In-tank robotic devices are not required.	• Soil around gunite tanks is contaminated. • Facility origin of many pipelines is unknown. As a result, unexpected flows could occur during cutting and capping operations. • The risk for worker contamination is much greater with this method. • The time required to complete operations is significantly greater using this method.
Commercial pipe plugs	• These plugs can be purchased off the shelf. • The cost of a commercial plug is less than that of a custom plug.	• Commercial plugs are designed for temporary use in testing pipe circuits and repairs. • To obtain a proper seal, pipes must be very clean, stable, and perfectly round at the ends. • Precise alignment is required for installation. • Radiation resistance of materials used in these devices is questionable.
Grout injection	• Grouting material for use in plugging pipes is readily available. • The cost of grout alone is less than the cost of designing a custom plug.	• This method is very expensive and complex to implement.

Technology Applicability

The Pipe Cutting and Isolation System will be deployed on other tanks at ORNL. The system is also applicable to tanks at other DOE sites, particularly the Hanford Site and INEEL. Industrial applications may apply as well.

The following list identifies implementation parameters and scale-up requirements for this technology:

- Pipe configurations for each tank should be thoroughly examined, keeping in mind that existing records may not accurately reflect the current configuration.

- Pipe cutting, cleaning, and plugging requirements should be determined: Which pipes require plugging? Do the pipes to be plugged require cutting and/or cleaning? If so, what are the desired lengths for cutting, and how much cleaning is required?

- Some modifications to the standard pipe plug will be required for pipes that are larger than the standard designs for 1.5-, 2-, and 3-inch-diameter pipes.

- Construction materials are selected based on environmental considerations and desired life expectancy of the plug (e.g., stainless steel was selected for the GAAT plug due to the potentially corrosive nature of the wastes in the GAAT).

- Tanks should accommodate operations of the MLDUA or ROV.

Considerations for future selection of this technology follow.

- This technology is useful at sites such as the GAAT where underground tanks have many openings that were once used for transferring waste.

- Sites that have tried external plugging of tanks and found it to be unsuccessful may opt to try this method of tank isolation.

Patents/Commercialization/Sponsor

Development and deployment of the Pipe Cutting and Isolation System was sponsored by the DOE OST, ER, and the Tanks Focus Area. Efforts are in progress to obtain patents on the pipe plugging technology. Pipe cutting and cleaning tools are available from hardware stores (portable band saw and drill motor) and adapted for this application. Devcon, an Illinois Tool Works Company in Danvers, Maryland, manufactures the sealant material.

The MLDUA, the robotic arm that moves equipment around in the tanks, was manufactured by SPAR Aerospace. SPAR Aerospace manufactures the robotic arms for the space shuttles. The Houdini robotic vehicle was produced by Redzone for the DOE Robotics Program through the Federal Energy Technology Center.

SECTION 5

COST

Methodology

This section compares the costs for tank isolation using the Pipe Plugging and Isolation System versus the baseline. The baseline is to review available design and installation drawings. The next steps are hand excavation and visual inspection to locate the pipelines entering tanks. The baseline involves cutting the line near the tank, plugging both sides to ensure no additional post closure leakage into the tank, and using grout to backfill the excavation area around the piping. The baseline technology of excavating around tanks and plugging pipes externally poses too many risks. Workers have been contaminated using this plugging method, and it has not proven successful.

The Pipe Cutting and Isolation System was developed in response to a critical need identified during remediation and treatability studies on the GAAT project. The need was for development of a safer, more effective method to isolate tanks. Greater safety was required for both workers and the environment.

The baseline costs presented below are taken from "Remediated Tank Isolation and Removal," a technology development need statement submitted to Tanks Focus Area by the Oak Ridge Site Technology Coordination Group and published online at http://www.em.doe.gov/techneed/.

Cost Analysis

An estimated cost comparison for deployment of the Pipe Cutting and Isolation System versus the baseline technology is provided in this section. With safety as well as GAAT retrieval and closure schedules driving the project, pipe cutting and isolation tools were developed as quickly and economically as possible. Off-the-shelf products were used for components when feasible.

The GAAT project is a multimillion dollar effort. Through this effort, trained operators, MLDUA and ROV equipment, and numerous resources were available for use in the deployments. Since this equipment was already available, the costs are not included in the cost estimate for the Pipe Cutting And Isolation System.

Capital, Operating, and Maintenance Costs
Estimated costs were reported by Oak Ridge for deploying system tools per tank versus the baseline technology. These costs are listed in Table 10.

Table 10. Estimated deployment costs for the Pipe Cutting and Isolation System versus the baseline technology

Technology	Activities performed	Cost per tank
Pipe Cutting and Isolation System	Cut, clean, and plug pipes	~$10,000
Baseline, external plugging	Excavate around tank, cut, and plug pipes	~$100,000

A rough, order-of-magnitude engineering estimate conducted by Oak Ridge for isolation of eight of the GAAT using the baseline technology resulted in an anticipated cost of ~$800,000 to locate, cut, and cap all the lines at the perimeter of each tank. The cost per tank for isolation of the Old Hydrofracture Facility (OHF) tanks is assumed to be similar to the GAAT costs. Therefore, the costs to isolate the five OHF tanks is estimated to be ~$500,000.

The cost for the Pipe Cutting and Isolation system are much less because hand excavation is not required. Direct labor and materials costs involved in cutting, cleaning, and plugging 3 to 4 pipes per tank are approximately $10,000 per tank. These costs are based on a robotic manipulation system being available with an operating crew that has been previously trained. The total cost to isolate the tanks is ~$80,000 for eight GAAT and ~$50,000 for five OHF tanks.

Cost Conclusions

Significant savings can be realized by implementing the Pipe Cutting and Isolation System as opposed to the baseline technology. As shown in Table 10, the Pipe Cutting and Isolation System costs an estimated $10,000 per tank compared to $100,000 per tank for the baseline technology. The following list identifies means by which cost savings are achieved when implementing the Pipe Cutting and Isolation System.

- Due to its simplicity, the Pipe Cutting and Isolation System can be implemented in much less time than it would take to implement the baseline technology. As a result, labor costs are less, and tank retrieval and closure schedules can be accelerated.
- Significant savings in cost are realized by adapting and using commercial, off-the-shelf products.
- Using existing robotic positioning devices that do not require any modifications generates significant savings. Modifying either the MLDUA or ROV would have added significant costs to the deployment effort.
- Additional savings are realized because additional tether-handling equipment, pumps, etc. are not required for implementation.
- Immense savings were realized on these GAAT deployments due to the infrastructure that provided many of the required resources.

SECTION 6

REGULATORY AND POLICY ISSUES

Regulatory Considerations

The GAAT at ORR are in the process of being closed. A remedial investigation and feasibility study was conducted, followed by a treatability study, to obtain information that would assist in closing these tanks in a safe, efficient, cost-effective manner and in compliance with regulations. In addition to the GAAT treatability study and GAAT Remediation Project, additional site-specific regulatory drivers for remediation of tank wastes at ORR include the following:

- Oak Ridge Federal Facility Agreement and Consent Order (between the U.S. Environmental Protection Agency [EPA] Region IV and Tennessee Department of the Environment and Conservation)
- Tennessee Department of Environment and Conservation Commissioner's Order for the Oak Ridge Reservation Site Treatment Plan
- DOE Order 5820.2A requiring treatment of transuranic waste for disposal at the Waste Isolation Pilot Plant
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980

Secondary waste
The baseline technology approach will generate wastes from excavation debris, personal protective equipment, excavation tools, plastic sheeting, containers, and samples taken for analysis of the surrounding soil and pipeline contents. These wastes will not be generated using the Pipe Cutting and Isolation System.

CERCLA Evaluation
This section summarizes how the Pipe Cutting and Isolation System addresses the nine CERCLA evaluation criteria.

1. Overall Protection of Human Health and the Environment
   - Plugging the tank openings with remote-controlled operations significantly minimizes radiation exposure to workers.
   - Tanks can be isolated faster, with fewer personnel, in much safer surroundings, thus reducing threats to human health and the environment.
2. Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)
   - The system was designed and deployed according to applicable regulatory requirements.
   - Established procedures and controls are in place to ensure compliance.
3. Long-Term Effectiveness and Permanence
   - This technology can help accelerate tank remediation and closure schedules.
   - Ground-water inleakage will be prevented, eliminating the need to handle and treat additional waste at a future date.

- The epoxy is resistant to radiation and has an expected life of 570 years with a contact source producing 100 rad/h.

4. Reduction of Toxicity, Mobility, or Volume through Treatment

   - The system prevents ground water from entering tanks and adding to waste volumes.

5. Short-Term Effectiveness

   Radiation exposure to workers is maintained as low as reasonably achievable (ALARA) through the following measures:

   - The plugging system is assembled away from the tank.
   - Use of complex equipment is avoided.
   - The tools are deployed in the tank through a riser pass-through port without opening the containment door, reducing worker exposure and eliminating the need for workers to wear full protective clothing and face respirators.
   - Established procedures and controls exist, and workers are thoroughly trained and qualified.

6. Implementability

   - Tools are easy to use.
   - Efficiency and cost are optimized by deploying tools while the MLDUA or ROV is in a tank for needed retrieval or closure activities.
   - Worker exposure is minimized.
   - Worker training and qualification programs and procedures are in place.

7. Cost data are provided in Section 5.

8. State (Support Agency) Acceptance

   - Both the state of Tennessee and EPA are parties of the Federal Facilities Agreement that covers regulatory issues and establishes requirements for management of tanks.

9. Community Acceptance is discussed below.

Safety, Risks, Benefits, and Community Reaction

Community groups and the general public have been involved in retrieval and isolation efforts on the entire GAAT project. DOE–Oak Ridge holds meetings with these groups on a regular basis to provide status updates and discuss activities.

DOE issues news releases on upcoming events and announces opportunities for public comment on all key program documents or proposed cleanup plans in area newspapers. Notices are also mailed to approximately 2,500 stakeholders.

Fact sheets providing technology updates are distributed to the public. Information is available to the public on the Internet on ORNL’s home page at www.ornl.gov/doe_oro/oro_home.html.

SECTION 7

LESSONS LEARNED

Implementation Considerations

Deployment of the Pipe Cutting and Isolation System revealed significant insights that can be applied to future applications. The following list identifies some of the lessons gained.

- Piping and layout drawings of DOE underground storage tanks are not always accurate. In the past, when new piping was added to tanks, documentation was not always updated to reflect the changes. Process knowledge and video inspections can be used to help determine current tank piping configurations.

- Contingency planning should be considered in the event that the isolation tools, MLDUA, or ROV are trapped by unexpected falling pipes, as occurred in one GAAT deployment. Not only did the cut section of pipe fall to the tank floor, but the remaining section of pipe that was attached to the tank ceiling also fell. The pipe was not securely attached to the ceiling and fell unexpectedly, trapping the cutting tool and MLDUA. The system was freed without any damage by using the MLDUA to break the saw blade on the Pipe Cutting Tool.

- The MLDUA has performed very reliably after thousands of hours of operations. Only minor problems have been encountered when compared to other in-tank systems.

- The design of the pipe plug using epoxy reduces the need for the pipe to be cleaned. The plug will work successfully on pipes that may contain some buildup, where alternative technologies require an extremely clean pipe for the plug to be effective. This design enabled a very simple approach in developing a cleaning tool that was easy to adapt, economical to build, and sufficient to perform cleaning operations.

Technology Limitations and Needs for Future Development

Technology limitations are discussed below. As additional deployments are made, required improvements and possible enhancements will be identified and analyzed.

- The Pipe Cutting Tool presents a hazard because of the sharp band saw blade. If this tool is not used with extreme care, the blade can cut through gloveport gloves as well as human flesh. Established procedures incorporate safety precautions. However, enhancements should be made in the future to reduce these risks.

- Visibility limitations and lack of depth perception hinder pipe cleaning operations. It can be challenging to position the Pipe Cleaning Tool, move the tool around the circumference of the pipe, and insert the tool into the pipe. Acceptable performance is achievable; however, it is time-consuming and frustrating. Possible means of improvement should be examined.

- Another limitation of the Pipe Cleaning Tool is the ability to operate the tool for only approximately 7 min before thermal protection fuses trip to protect the motor from overheating. The unit requires approximately 30 min to cool down enough for the fuses to automatically reset and another 2.5 min of operation becomes available. This limitation is due to the protective boot that has been placed over the motor ventilation ports to enable the cleaning tool to be decontaminated by the water decontamination system. Several approaches to avoiding this serious limitation in operation were analyzed, but no acceptable solutions were identified that met cost, schedule, and technical complexity limitations.

- The Pipe Cutting Tool has an operational time limit of approximately 8 min before automatically shutting down. This is not an issue due to the short amount of time that it takes the tool to cut through a pipe. Procedures are also in place to avoid overheating. Potential improvements for this tool should be examined in conjunction with efforts to improve the cleaning tool.

Technology Selection Considerations

The Pipe Cutting and Isolation System requires no external mechanical equipment such as a tether-handling system or grout pump. The system can be deployed through a minimum 23-inch-diameter riser. However, supporting infrastructure for the MLDUA or ROV must be available.

The Pipe Cutting Tool is useful for removing piping obstructions prior to tank retrieval and treatment operations. Problems can occur from cutting unsecured pipes, and deployment must be carefully planned to avoid creating obstructions from falling pipe.

APPENDIX A

REFERENCES

Babcock, S. M., R. L. Glassell, and B. E. Lewis. 1997. *Functions and requirements for the Gunite and Associated Tanks Pipe Plugging System.* Oak Ridge, Tenn.: Oak Ridge National Laboratory.

Fricke, K. E., and T. C. Chung. 1995. *Structural analysis of ORNL underground Gunite waste storage tanks.* Lockheed Martin Energy Systems, Inc., for presentation at the Fifth National Phenomena Hazards Mitigation Conference, Denver, Colo., November 8.

Glassell, R. L., S. M. Babcock, and B. E. Lewis. 1998. *Design, test, and operation description for the Gunite and Associated Tanks Tank Isolation System*, Version 1.0. Oak Ridge, Tenn.: Oak Ridge National Laboratory.

Glassell, R. L., and B. E. Lewis. 1999. *Initial performance report on the tank isolation tools deployed in the Gunite and Associated Tanks at the Oak Ridge National Laboratory*, Rev. 0. Oak Ridge, Tenn.: Oak Ridge National Laboratory.

Lewis, B. E., R. L. Glassell, and S. M. Babcock. 1998. *Tank isolation deployment plans and issues.* Oak Ridge, Tenn.: Oak Ridge National Laboratory.

Lockheed Martin Energy Research Corporation. 1998a. *Gunite and Associated Tanks Remediation Project. Modified Light Duty Utility Arm System pipe cleaning procedure.* GAAT-RP/P-149, Rev. 1.

Lockheed Martin Energy Research Corporation. 1998b. *Gunite and Associated Tanks Remediation Project. Modified Light Duty Utility Arm System pipe cutting procedure.* GAAT-RP/P-148, Rev. 1.

Lockheed Martin Energy Research Corporation. 1998c. *Gunite and Associated Tanks Remediation Project. Modified Light Duty Utility Arm System pipe plugging procedure.* GAAT-RP/P-134, Rev. 0.

Oak Ridge Site Technology Coordination Group. 1997. "Remediated Tank Isolation and Removal," in the Oak Ridge Technology Needs Database. Retrieved June 10, 1999 from the World Wide Web: http://www.em.doe.gov/techneed/tk10.html.

Rinker, M. W., J. A. Bamberger, F. F. Erian, T. A. Eyre, B. K. Hatchell, O. D. Mullen, M. R. Powell, T. J. Samuel, G. A. Whyatt, and J. A. Yount. 1998. *EM-50 Tanks Focus Area retrieval process development and enhancements, FY98 technology development summary report.* PNNL-12015, UC-721. Richland, Wash.: Pacific Northwest National Laboratory.

Tanks Focus Area. 1996. *Oak Ridge National Laboratory tank cleanup: A guide to understanding the issues.*

APPENDIX B

ACRONYMS AND ABBREVIATIONS

ALARA	as low as reasonably achievable
ARARs	applicable or relevant and appropriate requirements
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ER	Environmental Restoration
FY	fiscal year
GAAT	Gunite and Associate Tanks
GEE	Gripper End Effector
INEEL	Idaho National Engineering and Environmental Laboratory
MLDUA	Modified Light-Duty Utility Arm
OHF	Old Hydrofracture Facility
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
OST	Office of Science and Technology
PNNL	Pacific Northwest National Laboratory
ROV	Remotely Operated Vehicle